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Interactive comment on "High stresses stored in fault zones: example of the Nojima fault (Japan)" *by* Anne-Marie Boullier et al.

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General comments

The publication entitled 'High Stresses stored in fault zones: example of the Nojima fault (Japan)' by Boullier et al. encompasses the microstructural characterization of a rock sample that was retrieved from a borehole within the damage zone of the Nojima fault at some distance of the slip plane. The introduction sets the scene well with the current knowledge of shallow damage zones and coseismic off-fault pulverization, followed by some evidence of coseismic (high strain rate) damage observed at greater depth. The aim is to study coseismic damage and interseismic healing of damage zone rocks at substantial depth (>3 km), and to put constraints on the mechanical

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conditions that caused such coseismic damage. This is done by analyzing the thin section using various techniques, such as optical and electron microscopy, EBSD and X-ray Laue diffraction. The results show microstructures evidencing co- and interseismic deformation, such as pulverization textures and sealing of fractures by Laumontite. The authors use the structural relations given by the Laumontite sealing to argue for a coseismic formation of - or at least the simultaneous formation of - the pulverization texture. Moreover, the X-ray Laue diffraction results provide unique quantification of residual stresses stored in the sample. It is then discussed that these stresses were induced by coseismic stress wave loading. Last, there is some discussion on how such damage progresses with repeated seismic events.

The work and the results are excellent, and the authors focus the main message of the paper on the quantification of the residual stresses (e.g. the title, the abstract), and with reason. Together with the depth constraints of the damage, this paper shows that coseismic damage and pulverization may extent to a much greater depth and to a much greater distance than previously thought. This is also the point in the discussion where the authors could add an extra paragraph of in-depth discussion on coseismic loading conditions:

- For shallow damage zone pulverization, several formation mechanisms are currently under discussion: pulverization in compression, pulverization in volumetric extension, wrinkle-like pulses, supershear ruptures, and fluid-assisted decompression of rock are some loading (or rupture) mechanisms that are proposed for bulk pulverization. The results of this paper show that high enough strain rates for pervasive dynamic damage are reached at greater depth, and that compressive stresses are stored. Also, there are independent strain measurements, including directions, from the biotite (compressional) and the opening of veins (extensional). Even more, the sample's distance from the fault is very substantial (51.3 m) and outside the range of higher strain rates produced by 'normal' earthquake ruptures. Although the results of one sample cannot answer such a question unequivocally, it would be interesting to see the authors' view on the loading mechanism or rupture mechanism that can produce such dynamic damage nonetheless.

There are no major comments besides the one above, or they are covered in the manuscript (such as the small sample size). The manuscript is well structured and the length is justified. There are some minor comments, which are given below. The manuscript is of great interest to field geologist, rock physicists, and with some more discussion for seismologists as well. Therefore, I recommend a minor revision.

Specific comments

- The term residual stress is mentioned throughout the manuscript (starting at line 16, page 2). At line 20 (page 9) it becomes clear that the residual stress is a deviatoric residual stress (or Von Mises stress), calculated from residual deviatoric strain (line 2, page 9). It would help the reader if it is stipulated much earlier onward in the manuscript that a residual deviatoric stress is recovered from the sample, for instance in the introduction. Following this, the sentence at lines 6-9 (page 13) on the confining pressure at depth causing the residual stress becomes redundant, since this is the lithostatic and not the deviatoric component by definition.

- Line 27, page 2: The statement at the end of the sentence here is wrong. In the split Hopkinson pressure bar experiments, there are no shear stresses applied on the sample. The threshold recorded by Doan & Gary is a strain rate threshold. Using linear elasticity, such a strain rate threshold can be transformed into a stress rate threshold, although elastic properties are weakly rate dependent in this regime.

- Line 28-30, page 2: On the Yuan paper. Maybe the authors can add here something like: With increasing confining pressures, the strain rate threshold increases as well.

- Line 5, page 3: Sagy & Korngreen (2012) describe dynamic fracturing based on the branching of fractures. I am not sure it would classify as pulverization, also due to the tiny volume that was studied. Maybe replace pulverized by dynamically fractured.

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- This recent paper shows pulverization at depth as well, and might be cited here: Sullivan & Peterman (2017), Pulverized granite at the brittle-ductile transition: An example from the Kellyland fault zone, eastern Maine, U.S.A., Journal of Structural Geology

- The fact that only one thin section is subjected to in-depth analysis can be mentioned earlier, for instance in the introductory paragraph of section 3.1.

- What is the meaning of A exactly in line 6, page 12?

- A question raised by the observations of stressed sub grains due to ductility (dislocations) and the microfractures is: Would such residual stress be released by microfracturing in the vicinity? Are there geometrical relations that would show (or not show) such a relationship between the two microstructural expressions of damage?

- The residual peak stress of 100 MPa and mean stress of 141 MPa mentioned in the manuscript (presented in section 6.2, but mentioned thereafter and in the abstract) is confusing. These numbers are derived from a skewed probability distribution (Figure 13b), but the term peak stress implies from a rock mechanical point of view the highest stress (which is 500 MPa or so). Rather than peak stress, it should state the peak of the stress distribution is at 100 MPa or the modal value is 100 MPa.

- Line 11 and 12, page 15, on the drop of P-wave velocity. Such a stress drop is not an exclusive indicator for dynamic damage, merely an indicator for an increase in damage (however it has been created). Therefore, this statement is over interpretation.

Some technical comments are attached in the pfd-file.

Please also note the supplement to this comment:
https://www.solid-earth-discuss.net/se-2017-130/se-2017-130-RC1-supplement.pdf

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